Achieving Cost/Performance Balance Ratio Using Tiered Storage Caching Techniques: A Case Study with CephFS

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Background & Problem Statement

- STAR has implemented a Ceph Distributed Storage System primarily using the POSIX compliant CephFS for processing QA, recovering DAQ files, scratch space, and backup storage.
- Can fast SSDs speed up CephFS storage?
- Goal: Balance between IO performance and cost per GB without breaking the bank.
- Ceph Cache Tiering is not a native feature of CephFS (only with Ceph object storage). M. Poat, J. Lauret – "Performance and Advanced Data Placement Techniques with Ceph's Distributed Storage System", J. Phys.: Conf. Ser. 223 – To be published.
- Can we implement a low level caching mechanism that is undetected by Ceph and give us the IO performance we desire?
- Three low-level disk caching techniques investigated (Flashcache, dm-cache, and bcache).
- Multiple disk configurations were implemented into CephFS and single and multiple thread IO performance tests were run to see the performance impact.

Analysis Procedures

- Single and multi-thread IOzone performance tests were run across all devices.
- bcache and dm-cache configurations were implemented. (Flashcache is not supported by Scientific Linux and is no longer supported natively).
- bcache, dm-cache, bare HDD & 3x HDD RAID0 CephFS clusters were benchmarked with single-thread IOzone tests and multi-threaded, multi-client IOzone tests.

STAR Ceph Distributed Storage System

Configuration

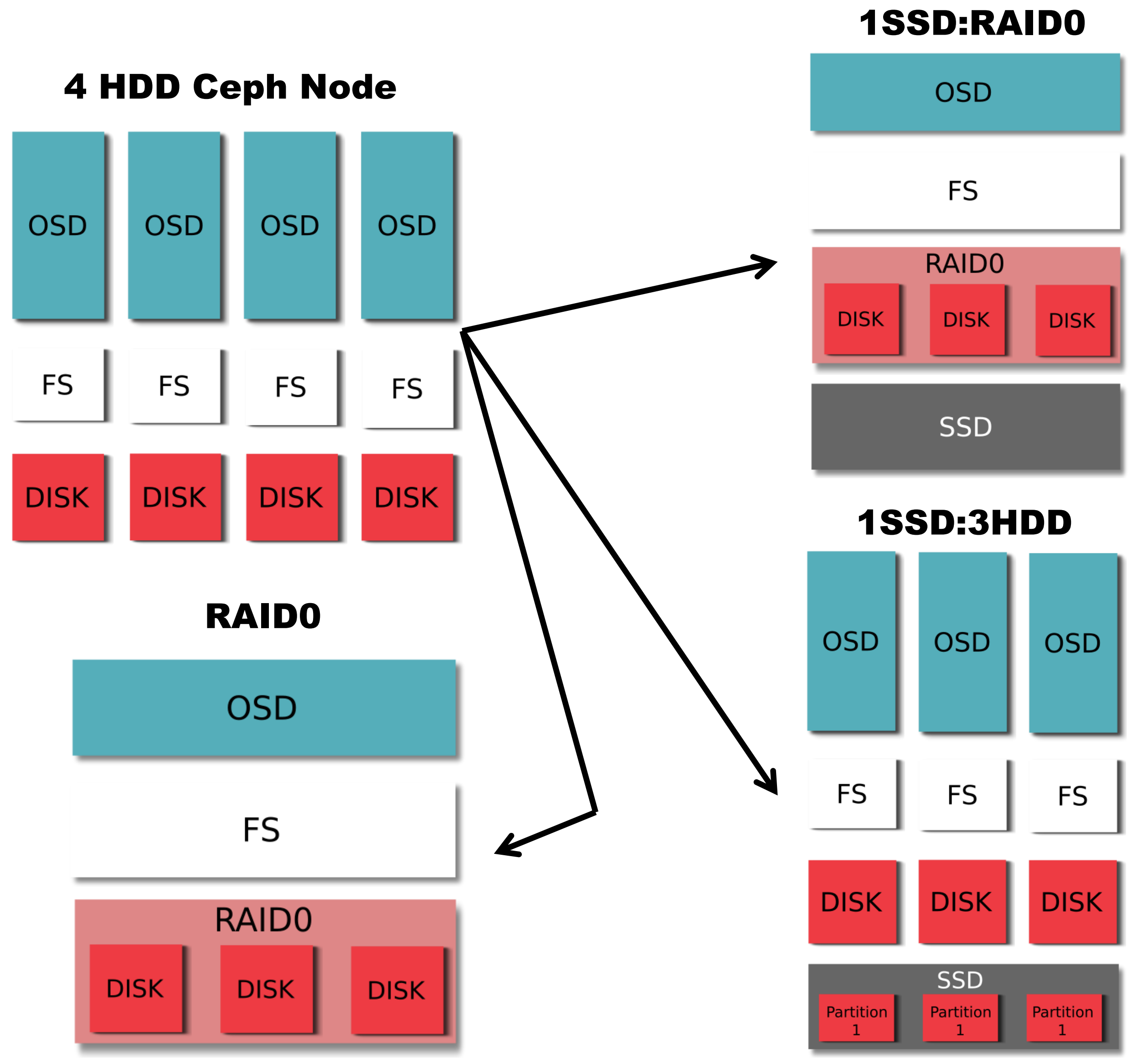
- 30 nodes with 4 – 2TB SAS HDD each.
- Replication 3, total of 80TB of redundant, fault tolerant storage.
- The primary use for Ceph is to leverage the POSIX compliant CephFS (NFS like) mountable storage for users.
- Applicable uses: processing QA, recovering DAQ files, scratch space, backup store.

Data Placement Techniques: Findings

- Ceph has built in performance based data placement techniques: OSD Pool Mapping, Primary Affinity, OSD Journals on SSDs, and Cache Tiering. Approach applied - past ACAT 2016 work.
- Efforts to replace one HDD per node with a fast drive (SSD), performance sought was not obtained.
- Performance gain is possible but at what cost?

Ceph Configurations

Stock 4 HDD Ceph Node configuration transitioned to clusters with 1SSD:3HDD, 1SSD:RAID0, and standalone RAID0 configurations.

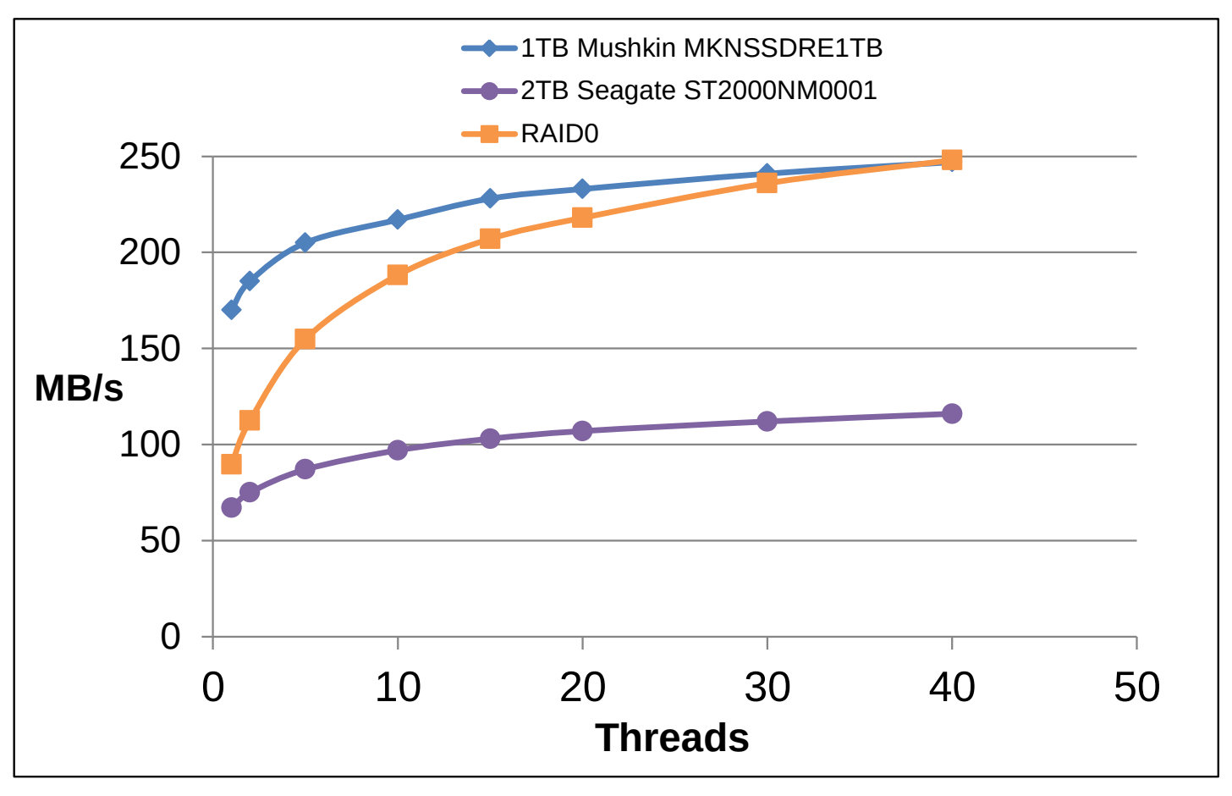


Disk Caching Techniques

Bare Disk

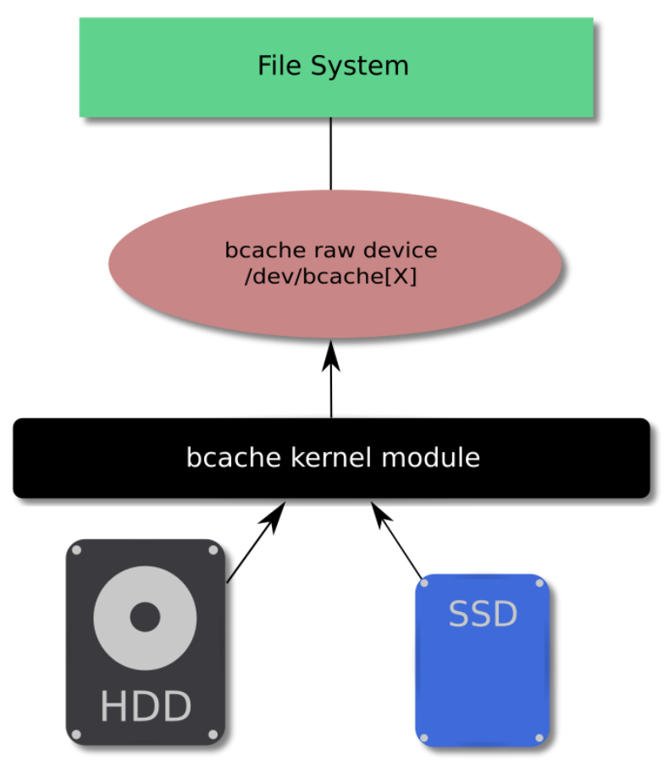
- 2TB Seagate ST2000NM0001 (HDD) and 1TB Mushkin MKNSSDRE1TB (SSD) used. RAID0 is composed of 3 HDD.
- IO Performance Test - 4096KB chunk sizes as a function of the number of threads increasing (x-axis) shown in MB/s (4096KB = Ceph block size).
- SSD performs ~2-2.5x faster than bare HDD.
- SSD outperforms RAID0 with low number of threads, near same performance at high number of threads.

IOzone – 4096KB Multi-Thread Write

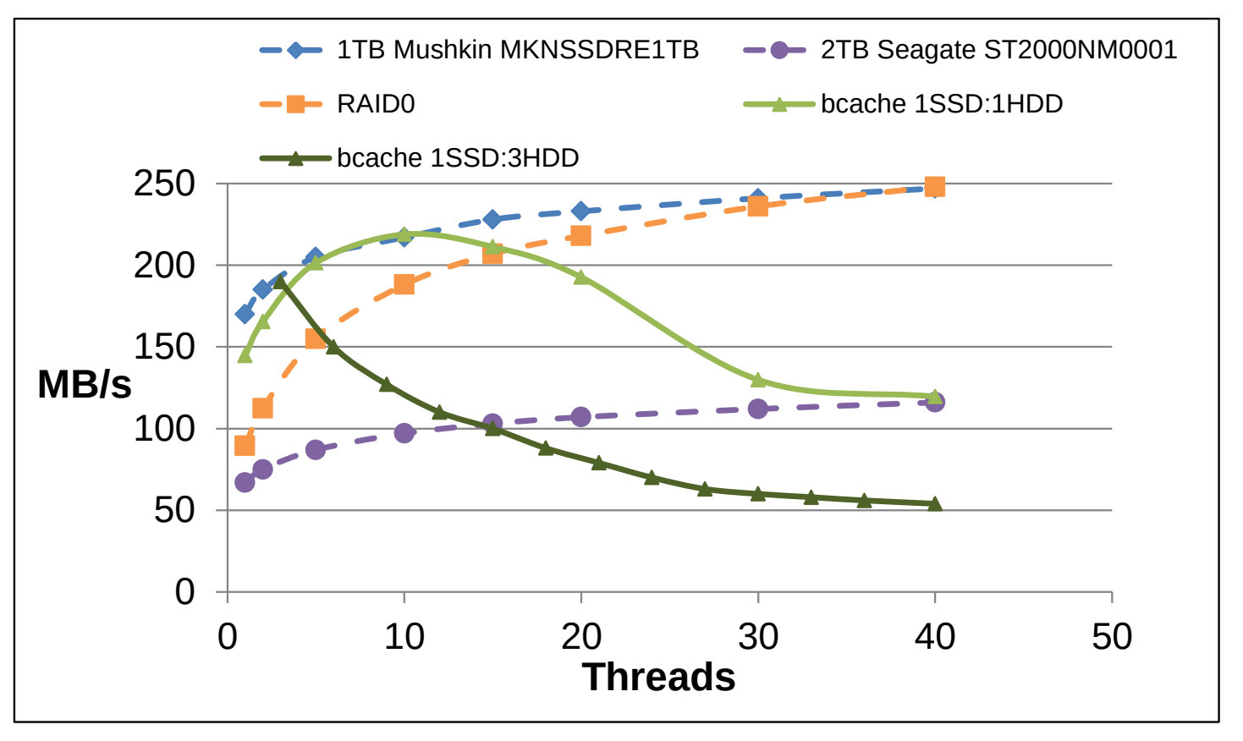


bcache

- Linux kernel block layer cache.
- One or more SSDs mapped to one or more HDDs to act as a cache.
- Green curve represents 1SSD:1HDD bcache device.
- IO performance converges with SSD at low number of threads and drops off at higher number of threads.
- 1SSD:3HDD (aggregate of all 3 devices) shows very poor performance. Not expected.
- IO is directed to SSD, bcache slows down IO under heavy load when multiple bcache devices are created.

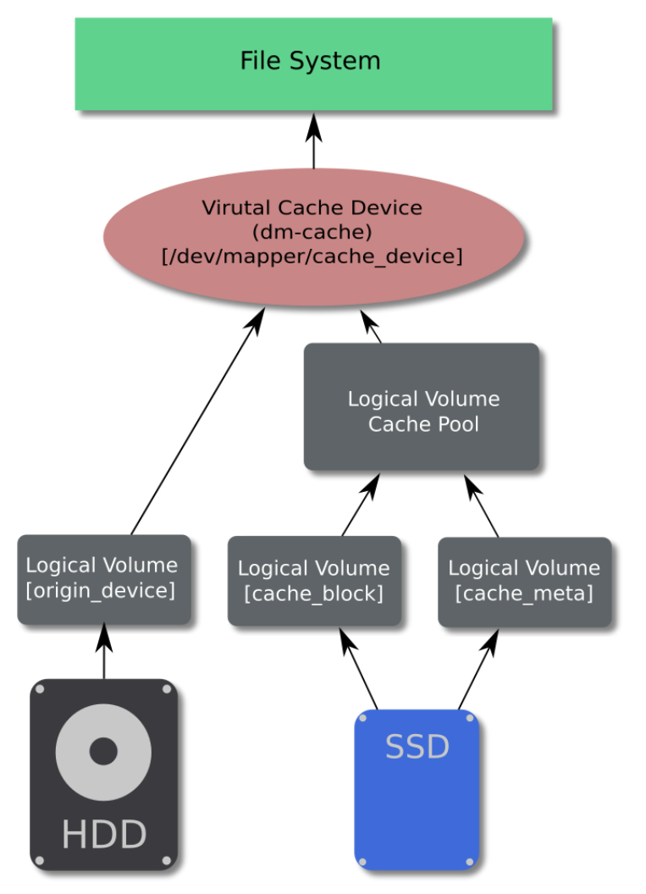


IOzone – 4096KB Multi-Thread Write

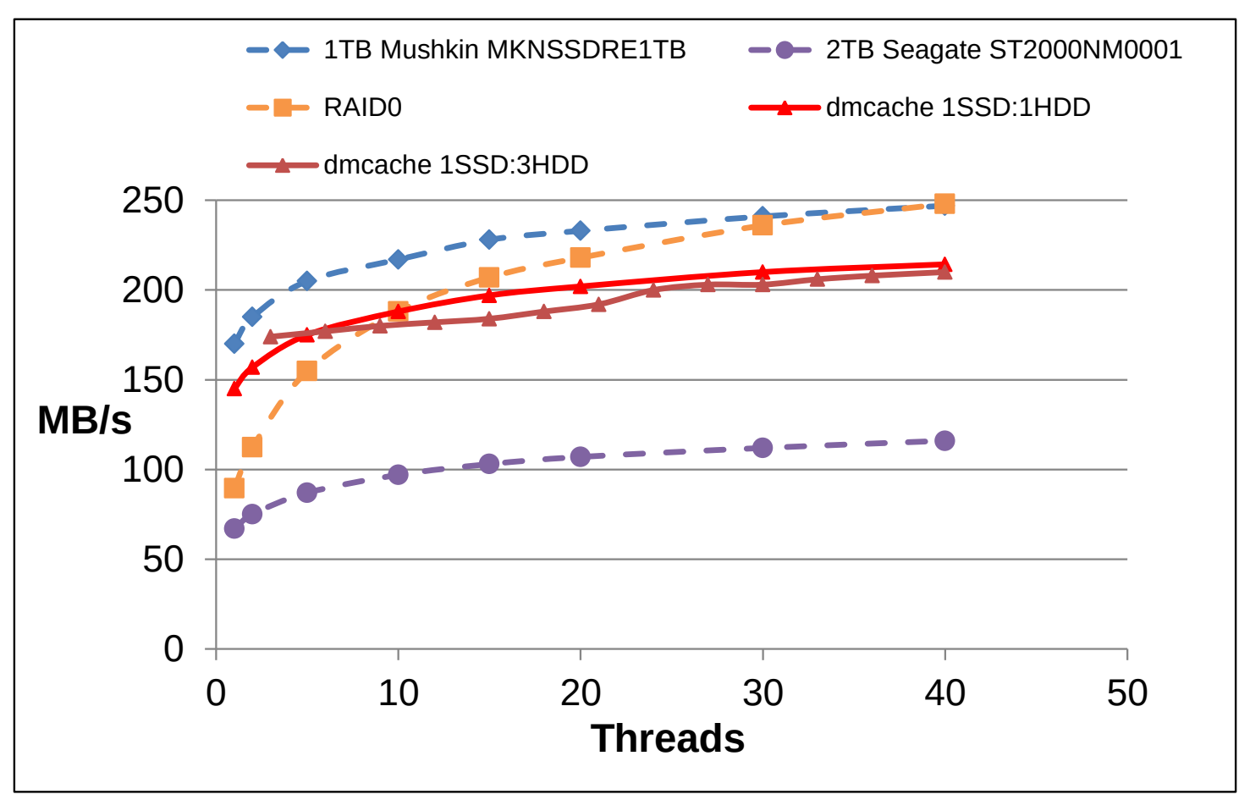


dm-cache

- Linux kernel device mapper caching technique.
- One or more SSDs can be mapped to one or more HDDs to act as a cache.
- dm-cache requires 3 logical volumes in total
  - 'Metadata' & 'Cache' Volume on SSD
  - 'Origin' Volume on HDD
- The dm-cache device is set to writeback.
- IO performance is similar with 1SSD:1HDD & 1SSD:3HDD – IO is set to write to SSD. Under heavy load, IO will writethough to backing HDDs.



IOzone – 4096KB Multi-Thread Write

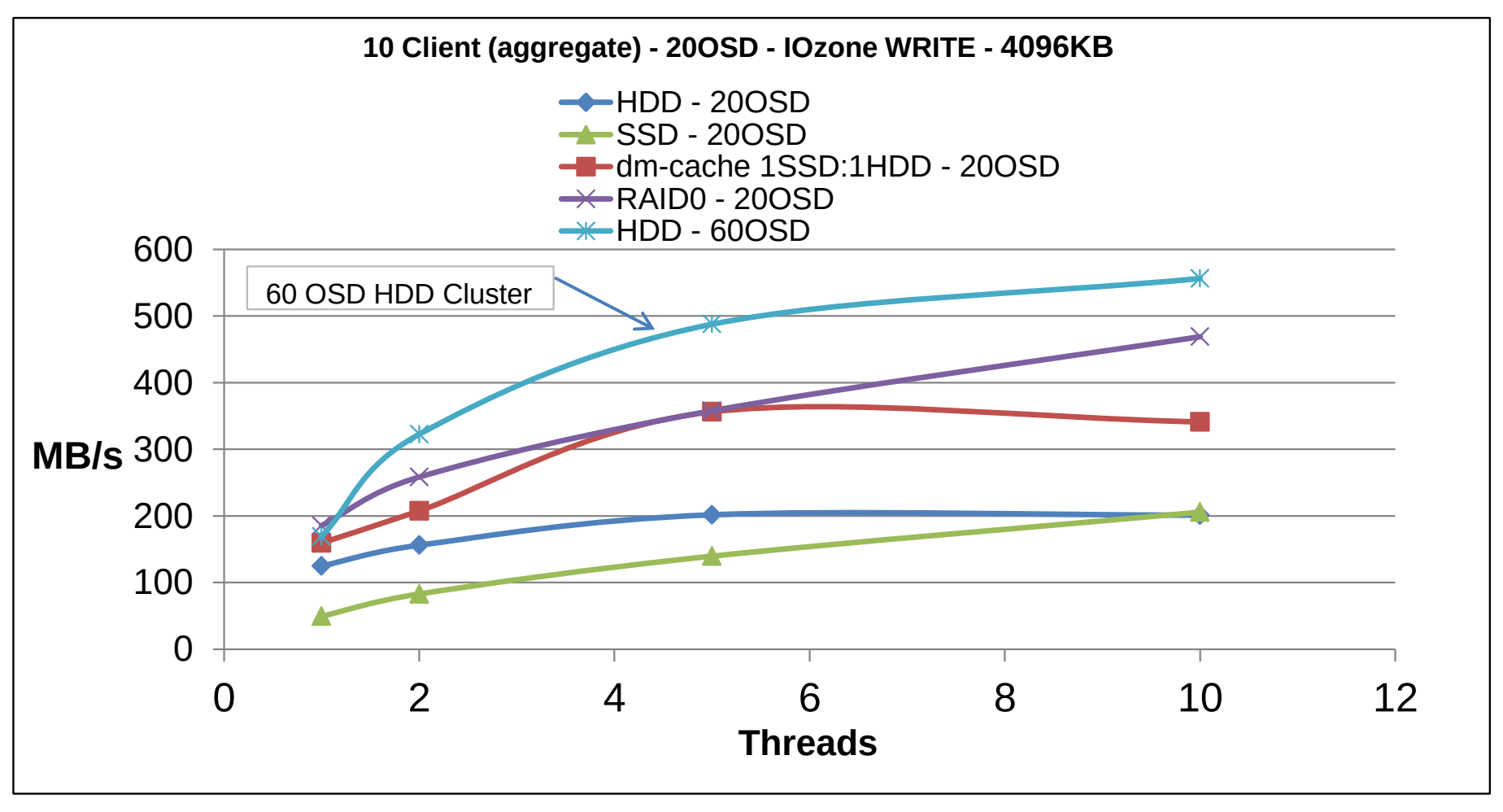


CephFS Performance Results

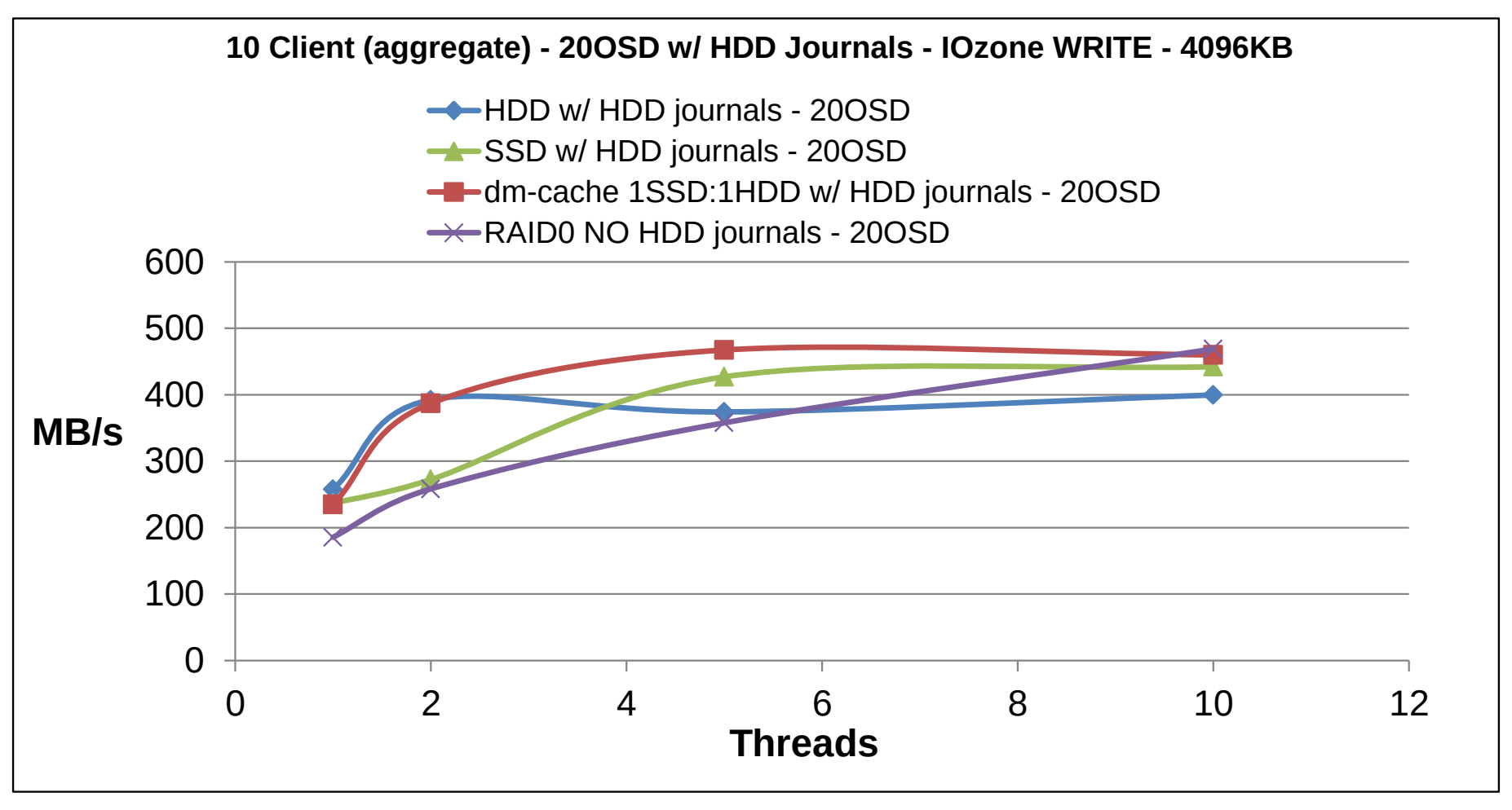
- 4 CephFS clusters made up of 20 OSDs each (HDD, SSD, 1SSD:1HDD dm-cache, & RAID0).
- 10 client IOzone 4096KB chunk writes, thread range 1-10 per client. Performance shown as aggregate.
- dm-cache performance is above SSD and HDD cluster, while the expectation would be between the two.
- dm-cache response to journal flush may be the reason for out-of-bound performance.
- SSD outperforms HDD in bare test, in Ceph context performance is flipped.
- Ceph OSD journals are bottleneck in SSD vs. HDD? →

- All Ceph OSD journals were then mounted onto a separate HDD (except RAID0)
  - ❑ SSD Ceph cluster ~3x performance increase
  - ❑ HDD Ceph cluster ~2x performance increase
  - ❑ dm-cache cluster ~0.5x performance increase
- SSD Ceph cluster with external journals = Faster IO.
- Journal write must 'sync' before proceeding to FS write. Drive dependent on ATA_CMD_FLUSH handling.
- Bare SSD Ceph cluster - lack of PLP (**P**ower **L**oss **P**rotection) cause journal flush to FS = latency.

10 Client IOzone Write into CephFS



10 Client IOzone Write into CephFS



Cost Analysis

- Current 120 2TB HDD cluster – Cost $14,400.
- In bare test - Consumer grade SSD - 4.5 times cost impact with only 2.25 times performance increase (Must test in Ceph before large purchase).
- 120 2TB Consumer SSD cluster – Cost $64,800.
- 120 2TB Enterprise SSD cluster – Cost $126,000.
- 1 Enterprise SSD:3HDD may positively impact performance but cost over HDD only cluster = $31,500 (~ x2 base cost).

Config	Avg. Speed @ 4096KB	Cost	Cost per MB/s	Cost per TB	Total space w/ 4 slot
2TB HDD	100MB/s	$120	$1.20	$60	8TB
2TB Consumer SSD	225MB/s	$540	$2.40	$270	8TB
2TB Enterprise SSD	540MB/s	$1050	$1.95	$525	8TB
dm-cache w/ ConsR. SSD + Jrnl. HDD w/ PLP	200 MB/s	$480	$2.40	$240	4TB

Conclusion

- While bare tests show performance gain using SSD over HDD, CephFS performs the best with a 'Stock' 4 HDD (120 OSD) configuration.
- RAID0 shows good performance from standalone test. In Ceph context, number of OSDs matters most. RAID0 not beneficial.
- Not all SSDs are the same, featureless SSDs may cause worse performance than HDDs in Ceph due to journaling flush-sync. Mushkin drives we used perform poorly in Ceph.
- dm-cache seems to show more stable performance than bcache. However, dm-cache would not perform well with our SSDs unless the journal is offloaded to a separate device.
- Cheap SSDs cannot help with performance gain. Enterprise models (with PLP) must be considered for performance increase. Cost for upgrade is significant.

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